Claims

1. A catalyst system that reduces polymeric fouling, the catalyst system comprising:

at least one titanate compound;

at least one aluminum compound; and

an antifouling agent comprising one or more of a phosphonium or phosphonium salt.

2. The catalyst system of claim 1, wherein the antifouling agent comprises one or more of a tetraalkyl phosphonium halide, a phosphonium malonate, a trihexyltetradecylphosphonium halide, a tetrabutylphosphonium halide, a tetrabutylphosphonium tetrahaloborate, a tetrabutylphosphonium halide, and a tetrabutylphosphonium hexahalophosphate.

3. The catalyst system of claim 2, wherein the antifouling agent comprises one or more of: tetrabutyl phosphonium halide, tetrabutylphosphonium malonate, trihexyltetradecylphosphonium bromide, tetrabutylphosphonium iodide, tetrabutylphosphonium tetrafluoroborate, tetrabutylphosphonium chloride, and tetrabutylphosphonium hexafluorophosphate.

4. The catalyst system of claim 1, further comprising a non-polymeric ether compound.

5. The catalyst system of claim 4, wherein the non-polymeric ether compound is tetrahydrofuran, a dioxane, or tetrahydropyran.

6. The catalyst system of claim 1, wherein at least one of the titanate compounds is an alkyl titanate.

7. The catalyst system of claim 6, wherein the alkyl titanate has the structure $Ti(OR)_4$, where R is a branched or straight chain alkyl radical comprising from 2 to 8 carbon atoms.

8. The catalyst system of claim 6, wherein the alkyl titanate is chosen from tetraethyl titanate, tetraisopropyl titanate, tetra-n-butyl titanate, or 2-tetraethylhexyl titanate.

9. The catalyst system of claim 1, wherein at least one of the aluminum compounds has the structure AlR'3 or AlR'_2H, wherein R' is a branched or straight chain alkyl radical comprising from 2 to 8 carbon atoms.

10. The catalyst system of claim 1, wherein at least one of the aluminum compounds is chosen from triethylaluminum, tripropylaluminum, tri-iso-butylaluminum, trihexylaluminum, or an aluminoxane.

11. The catalyst system of claim 1, wherein a molar ratio of total titanate compound to total aluminum compound is from: 1:10 to 1:1, 1:10 to 1:2, 1:10 to 1:3, 1:10 to 1:4,

1:10 to 1:5, 1:10 to 1:6, 1:10 to 1:7, 1:10 to 1:8, 1:10 to 1:9, 1:9 to 1:1, 1:8 to 1:1, 1:7 to 1:1, 1:6 to 1:1, 1:5 to 1:1, 1:4 to 1:1, 1:3 to 1:1, or 1:2 to 1.

12. The catalyst system of claim 1, wherein a molar ratio of total titanate compound to total antifouling agent is from: 1:10 to 1:0.01, 1:10 to 1:0.05, 1:10 to 1:0.1, 1:10 to 1:0.3, 1:10 to 1:0.5, 1:10 to 1:0.7, 1:10 to 1:1, 1:10 to 1:2, 1:10 to 1:3, 1:10 to 1:5, 1:5 to 1:0.01, 1:3 to 1:0.01, 1:2 to 1:0.01, 1:1 to 1:0.01, 1:0.7 to 1:0.01, or 1:0.3 to 1:0.01.

13. The catalyst system of claim 4 or claim 5, wherein a molar ratio of total titanate compound to total non-polymeric ether compound is from: 1:10 to 1:0, 1:5 to 1:0, 1:3 to 1:0, 1:2 to 1:0, 1:1 to 1:0, 1:0.5 to 1:0, 1:0.3 to 1:0, 1:0.1 to 1:0, 1:10 to 1:0.1, 1:10 to 1:0.5, 1:10 to 1:1, 1:10 to 1:2, or 1:10 to 1:5.

14. A method for selectively producing 1-butene, the method comprising: contacting ethylene with a catalyst system to oligomerize the ethylene to selectively form 1-butene, wherein the catalyst system is as defined in any of claims 1-13.